Monitoring Methods for Codling Moth

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A Workshop Sponsored by WSU Cooperative Extension
and the IFAFS and RAMP grants

Management of Our Key Pest – Codling Moth
Developing a Realistic, Practical Plan to Control
Codling Moth on Your Site

History: Monitoring codling moth (CM) in orchards has always been a challenge. For many years fermented molasses mixtures placed in a pan or glass jar were used as liquid bait. This monitoring system was attractive to CM, as well as many other moths. If traps were not checked often the moths would sink to the bottom of the liquid, making it difficult to make proper identifications. Black lights were also used as a monitoring system. These monitoring systems had the advantage of attracting both sexes though they seemed to be biased towards attracting mated or older female moths. Larval sampling, or the damage caused by larvae, has always been a good method of estimating CM populations in orchards.

For many years entomologists have shown that female moths placed in a cage inside a trap would attract and capture CM males. Identification of the CM sex pheromone by Wendell Roelofs in 1971 was a significant event in entomology and opened up the possibility of a new kind of monitoring system. While several chemical components of the CM pheromone have been identified, one component, codlemone, has always been the most attractive. Lures were developed by placing codlemone in or on a substrate that would slowly release it over time. When these pheromone lures were placed in different kinds of traps it was found that male CM could be captured and these captures reflected activity in an orchard. Thus a new CM monitoring system, the pheromone-baited trap, was born.

Many factors can combine to influence the capture of CM in pheromone-baited traps. It is known that not all moths that approach a trap enter and are captured. Even in a laboratory wind tunnel only 70-80% of moths that respond to a pheromone signal actually fly to and touch the pheromone source. In field studies where moths have been released in cages or large outdoor wind tunnels 50-70% of released moths can be captured over a 5- to 7-day period. When CM moths are marked and then released in an orchard only about 10% are recaptured.

In order to make sense of any monitoring system it is important to control as many variables as possible. One variable that can influence CM capture in traps is the number of traps placed in an area. It is well known that as the number of traps per area increases the number moths captured per trap declines but the total number of moths captured per area increases. What does this mean? A picture can be worth a thousand words, and the relationship is shown in Fig. 1A. What does this mean? It means that you have to be

aware of this relationship if you are going to use a pheromone trap to measure a CM population and determine the risk of fruit injury. More about this use of pheromone traps appears later in this paper.

Another variable that can be managed in a pheromone trapping system is the rate of pheromone released from a lure. Ideally, the pheromone release rate from a lure would be constant until the pheromone ran out (Fig. 1B). Unfortunately, the first pheromone lures we used had a pheromone release rate that declined rapidly over time (Fig. 1B) and the pheromone in the lure changed from an attractive form to a repellent form. The take home message from this information is that you should always remove old lures from traps when they are being replaced with new lures.

We have tested many lures, and I will share the methods used to evaluate them and some of the results to introduce the principles associated with how to use different lures. When testing different lures we standardize as many factors as possible so that we can reduce variability and only see the differences in lures. We use a standard trap for all lures. We rotate the lure-baited trap each time we check it to remove the effect of location, i.e., “hot-spots,” in the study area (Fig. 2). We duplicate the lure evaluation test in 5 or 6 different sites. Finally, we evaluate all the “high-load” (10X) lures in an orchard treated with 400 hand-applied dispensers per acre.

There are various ways of comparing different kinds of lures. In most tests we include a “standard” lure, one with which we have a lot of experience. We compare the capture of moths in traps baited with the “standard” lure that is aged over the entire test period with the same lure that is replaced, or renewed, in each trap rotation period, i.e., every 9 to 12 days (Fig. 2, red bar versus green bar). Thus we are comparing the performance of an aged lure with a fresh lure. A new kind of lure could then be aged throughout a test period (blue bars in Fig. 2) and compared to the “standard” lure, both fresh and aged. In this way we could test how long a lure would last before it needed to be changed. Another way to show the same data is to plot capture of moths relative to the standard lure that is new every trap period (green dotted line, Fig. 2). Capture of moths in traps baited with other lures is plotted relative to the fresh standard; for example, the standard aged lure (red line, Fig. 2) catches the same relative number of moths in the first period but only about half the number of moths in the next period and many fewer moths in the remaining periods. The new lure (blue line, Fig. 2) catches many more moths relative to the non-aged standard lure (green dotted line) in the first period and about the same number of moths throughout most of the rest of the test period. While this is a hypothetical situation, it mimics the kinds of information we have obtained in lure evaluation studies over the past decade.

Lures used for monitoring codling moth look and behave differently in releasing pheromone. Fig. 3A-D shows examples of these kinds of lures. The red rubber lure, also called the red septum, is show in Fig. 3A. This lure is used for both a 1X and 10X lure, depending on the pheromone loaded into it. Fig. 3B is the grey rubber lure (septum) and is also used as a “1X” and “10X” lure depending on the pheromone load[MD1]. Fig. 3C is the SuperLure. This lure has a reservoir containing pheromone. The pheromone is

released at a rate mimicking that of a “10X” lure. Fig. 3D is the BioLure. This lure also has a reservoir containing pheromone. A semi-permeable membrane regulates the release of pheromone at a rate mimicking that of a “10X” lure.

When we started working with pheromone monitoring systems the main lure type used was a red rubber septum (Fig. 4) loaded with 1 mg of the CM pheromone, codlemone, which I will refer to as a 1X-type lure. We evaluated this 1X lure as described above and found that it provided a fairly constant attraction to CM for about 3 weeks in the first generation and 2 weeks in the second generation (Fig. 5).

Attempts to develop longer lasting 1X-type lures resulted in companies using different substrates that released pheromone at a slower and more consistent rate over longer periods of time compared to the red septum. The data in Fig. 6 are from a study where we compared four 1X-type lures; a red septum (aged and changed every rotation – 10 to11 days), a grey rubber septum (Trécé L2 lure), a membrane-type lure (BioLure, Suterra, Inc.) and a wafer-type lure (lure tape). In the first generation the aged red septum captured the same number of CM as the fresh red septum (dotted line in Fig. 6) for 21 days, but thereafter it captured significantly fewer moths. The grey septum appeared to behave like the aged red septum except for the last time period where it captured as many moths as the fresh red septum. The lure tape (Hercon) was the most consistent monitoring substrate. It captured as many or more CM as the fresh red septum over the entire duration of the test, 53 days. In the second generation a similar behavior was observed for the aged red septum except that is caught significantly fewer moths in the 13-21 day period (Fig. 7). The grey septum captured as many CM as the fresh red septum during the entire period, 67 days. The lure tape captured moths equal to the fresh red septum for 45 days but thereafter captures dropped off (Fig. 7).

As we moved into mating disruption programs to manage CM we found that the 1X-type lure was not good at detecting moths. When we increased the lure load to 10 mg (10X-type lure) we could then detect some CM activity in pheromone-treated orchards. We conducted the same kinds of aging tests with the red 10X-type lure. We found that it also provided a constant attraction to CM for 3 weeks in the first generation and 2 weeks for the second generation (Fig. 8).

Attempts to develop longer lasting 10X-type lures resulted in new lures becoming available for testing. We compared the lure with which we had the most experience, the 10X red septum, to a new lure provided by Phero Tech, the SuperLure (also called the “bubble lure”). In this study, capture of moths in the SuperLure was compared to captures in traps containing an aged or fresh 10X red septum. As expected, we found that the aged 10X red septum only lasted 19 days in the first generation while the SuperLure (aged) captured as many moths as a fresh 10X red septum for 57 days (Fig. 9, solid blue line). There was also no difference in capture comparing a fresh SuperLure and an aged SuperLure over the entire test period in the first generation (Fig. 9).

In the second generation the SuperLure again captured the same number of moths through 48 days as a fresh 10X red septum but thereafter captures dropped off in the last period, 49-60 days, suggesting that the SuperLure had been depleted (Fig. 10).

In another study a 10X red lure that was aged for 27 days, then replaced, was compared to a SuperLure and a 10X BioLure (Suterra), both of which were aged for 54 days. In the first 27 days the SuperLure and BioLure captured about equal numbers of moths while the 10X red septum lure captured fewer moths from days 10-27 (Fig. 11). When a new 10X red septum was used (starting on day 28), moth captures were the same as the SuperLure over the next 18 days (days 28-45). By the last 9-day period (days 46-54) the SuperLure again captured more moths than the 10X red septum. These data indicate that the SuperLure was better at attracting moths than a 10X red septum even when using our guidelines for replacement, though in this test the change interval was longer than the recommended 21 days. The BioLure captured about as many moths as the SuperLure through day 36; however, thereafter it captured significantly fewer moths.

In the second-generation study, using these same lures, similar results were observed. Here the 10X red septum was changed every 18 days, a slightly longer interval than we would recommend, and the other lures were aged for 54 days. The SuperLure captured the same number of moths as the 10X red septum, changed every 18 days, over the entire period; the BioLure captured as many moths as the SuperLure through about day 27 and thereafter captured significantly fewer moths. These data suggest that the SuperLure lasted for at least 54 days in both generations while the BioLure lasted about 5 weeks in the first generation and 4 weeks in the second generation (Fig. 12).

We have also had limited experience with the MegaLure manufactured by Trécé. This is a grey septum loaded with more pheromone to mimic a release rate of a 10X-type lure. This lure seems to last as long as the SuperLure, 50 to 60 days in the first generation, and about 6 weeks in the second generation.

Based on our research, the number of days (weeks) that a lure should be used for monitoring CM in mating disrupted orchards is shown in Table 1. Changing lures based on these guidelines should help you maintain a consistent monitoring environment and improve the reliability of your monitoring program.

Table 1. The length of time high-load pheromone lures (10X type) should be used in mating disruption orchards.

Lure type	Duration 1st generation	Duration 2nd generation
10X red septum	3 weeks	2 weeks
SuperLure	6-8 weeks	6 weeks
MegaLure	6-8 weeks	6-8 weeks
BioLure (10X)	4-6 weeks	4 weeks

All of the 10X type lures have been evaluated in orchards treated with 400 hand-applied dispensers per acre (Isomate-C Plus). We know that in a conventional orchard, no

pheromone treatment, the 1X-type lures capture more moths than the 10X-type lures (Fig. 13). We also know that in an orchard treated with 400 dispensers per acre the attraction of the 1X lures declines dramatically (Fig. 13) while the attraction of the 10X-type lures increases. We do not have good comparative studies of these lures in orchards treated with lower rates of dispenser, that is 200 per acre. Since most growers in Washington are using pheromones at this rate we need to know which lures are attractive in these kinds of situations. In 2003 several researchers will be comparing 1X and 10X pheromone lures in orchards treated with different numbers of pheromone dispensers.

Trap placement: The location of a trap in the tree can influence its capacity to capture CM. Several studies have shown that traps placed in the upper third of the tree capture significantly more moths than those placed at mid-canopy. Dr. Alan Knight also showed that traps placed on a pole above the tree canopy captured very few moths. In conventional or mating disruption orchards we recommend that pheromone traps be placed high in the canopy. We also have learned that if a pheromone trap is placed too close to a hand-applied dispenser its ability to capture moths will be greatly reduced. To avoid this situation we recommend that no dispensers be placed in the tree, or even in a few trees around, where the pheromone trap is placed. This practice will help increase the apparency of the trap to moths in the orchard.

Trap types: We have compared several types of traps for their ability to capture CM. These different kinds of traps are shown in Fig. 14 along with data comparing the average number of CM captured when all were baited with the same lure type. There was essentially no difference between the Pherocon 1CP, Multipher-II, and IOBC carton-type traps. The large delta trap consistently captured more moths than the other traps. The reason for this was found to relate directly to this trap's larger sticky trapping surface. When the trapping surface was reduced to the same size as the other traps (Pherocon 1CP and IOBC carton trap) there was no difference in the number of moths captured. The Multipher II trap is a non-saturating trap, which means that it has no sticky trapping surface to get dirty, so it might have some advantage in orchards with high pest densities.

Trap checking and maintenance: Traps should be checked on a regular basis, at least weekly, and the moths should be removed from the trapping surface. If a trapping surface becomes dirty it will have a reduced capacity to capture moths. We recommend that a trapping bottom be changed after the accumulated number of moths exceeds 30 in a trap. Remember never to leave an old lure inside a trap when replacing it with a new one.

Moth capture thresholds: For many years we have used CM moth captures in pheromone traps to estimate the need to apply a control treatment. The challenge of predicting fruit injury from male moth captures is that you are measuring one thing, male numbers, and from this inferring female numbers and therefore the number of eggs laid and thus the number of fruits injured. Male moth capture is only an indirect measure of risk of fruit injury. All of the factors discussed above will change male moth capture and thus affect any relationship between catch and risk of fruit injury.

Researchers in British Columbia were some of the first to suggest using CM moth captures as thresholds for applying control treatments. Based on their experience and some experiments, they established that a capture of two moths in the same trap on two consecutive weeks justified the need to apply a control. This threshold was for conventional orchards because at the time they were developed mating disruption was not a control option. Apple growers in British Columbia still use the above threshold to manage CM. In Washington, a similar threshold system was developed but was based on an accumulation of moths in a trap over a treatment window. Moths in a trap are accumulated over a period from first moth capture (Biofix) to first egg hatch (250 degree-days). During this period if 5 or more moths are captured then a control is justified at the egg hatch timing. After a treatment is applied moth captures are again accumulated and if the threshold, 5 moths, is again exceeded another control is applied. The Washington threshold is lowered to 2 moths in a trapping period in the second generation.

Both of the CM thresholds above are based on use of one pheromone trap every hectare or 2.5 acres. If fewer traps are used then two things can occur. First, it is known that as the number of traps per area declines the number of moths captured per trap increases. This relationship was discussed earlier (Fig. 1) but is again shown here in Fig. 15. For the sake of discussion, we can consider that the number of moths captured in traps placed at a density of one every hectare (2.5 acres) would be one. Then if you chose to use only one trap for every 10 acres you could expect to catch about 4 times as many moths. It is not clear how to adjust the CM capture thresholds for trap densities lower than one per 2.5 acres. Certainly, if you did not adjust thresholds you would be taking a conservative approach and probably applying insecticides more often than needed. Another problem with using one trap every 5 or 10 acres is a lack of resolution of the CM population in the orchard. More traps give a better idea of where the CM problem is located and can allow for more localized or directed treatments, such as sections of the orchard or only threatened borders.

We have developed thresholds for 10X-type traps for use in mating disruption orchards. Fig. 16 shows the thresholds currently recommended for apple orchards using full rates of hand-applied pheromone dispensers. In the first generation an accumulation of more than 4 moths justifies consideration of an insecticide as a supplemental control. If captures exceed 10 moths, then a full insecticide program should be used to supplement the mating disruption. In the second generation the thresholds are reduced by half. While it is not clear why, it is a consistent observation that the pheromone trap does not seem to be as efficient a measure of CM populations in the second generation compared to the first.

It is important to realize that CM moth capture thresholds are guidelines, NOT absolute values. Thresholds are based as much on trial and error as experimentation. Many crop consultants and growers have successfully used CM moth capture thresholds to reduce insecticide use in conventional and mating disruption programs. The key is to adopt a system in which you are confident and stick to it. Standardization is critical.

Standardized CM Monitoring System

- Choose the lure or lures you are going to use and stick with them.

- Choose a trap type and stick with it.
- Maintain traps and lures religiously – i.e., change bottoms and lures as needed.
- Work with a standard trap density based on a good understanding of the orchard and pest pressure.
- Keep records and compare patterns of capture from generation to generation and year to year.

By building your own trapping system and remaining consistent you will gain confidence and understand the weaknesses of the system. Monitoring certainly costs money but when done well it can more than pay for itself, both in reduced pest control costs and in confidence in knowing what CM is doing in your orchard.

Other monitoring methods: Black light traps have been used to monitor CM for many years. They have the advantage of capturing both male and female moths, and their attraction is not affected by pheromone treatments in the orchard. It is likely that black light traps are biased to mated or older females. Black light traps have need of a power source, tend to be rather expensive and attract a lot of other moths and night flying insects, adding to the difficulty of counting only the insects of interest.

Dr. Doug Light (USDA-ARS) has recently discovered a plant volatile that is attractive to CM. This is commonly known as the pear ester and has been commercialized by Trécé as the DA lure. When put in a grey septum, this new attractant can be placed in a trap and used to monitor CM. The pear ester attracts male and female CM in about equal numbers. It is long lasting, about 8 weeks. Its attraction is not affected by pheromone in mating disruption orchards. It is more attractive to CM in walnut, less attractive in apple, and even less attractive in pear orchards. There is some indication that the pear ester could have differential levels of attraction to CM in orchards with different apple cultivars. We are not sure of the area of attraction of the DA lure. We are still learning how to use the DA lure but certainly it has provided a new way to monitor CM, especially in mating disruption orchards. Currently, there are several proposed changes in the DA lure technology aimed at improving its performance.

Visual inspection of apple orchards for CM injury has high value and does not take a great deal of time. It is not necessary to handle fruit or climb ladders to get a valid assessment of CM injury in an orchard. It is more important to look at more trees than spend a lot of time looking at a lot of fruit on a few trees. The method we have used to monitor CM injury is to position ourselves so that we can see fruit in the top and bottom of a tree. We begin looking at fruit at the top of the tree and count only those fruits where we can see the entire half. We move from the top to the bottom looking at 30 to 40 half-fruits (15 to 20 whole fruits) and record the number of fruits injured. At the end of the first generation you should inspect 50 trees per orchard block of about 10 acres. The percent fruit injured is calculated by using the total injured fruits divided by the (total half-fruits/2). For example, if you looked at 40 half-fruits on 50 trees that would equal 1000 whole fruits. If you found 5 injured apples the percent injury would be 0.5 (5/1000 x 100). The advantage of this method is that it gives you an idea of where damage is occurring, and it is almost always an over-estimate of actual damage in the orchard.

Regular inspection of border trees in the second generation or revisiting areas where damage was detected in the first generation are good practices to use to help with the detection of infestations that might not have been indicated by pheromone trap captures.

Placing a cardboard band around the tree trunk is another method of monitoring CM larvae. This is only a method to tell you where and if CM has survived in the orchard. It is labor intensive but can provide some valuable insight, along with cullage assessments of fruit, into potential problems and their location. The method we have used is to place a cardboard strip, about 2 inches wide, around the base of the tree trunk. This can be stapled to the tree and left for a considerable amount of time, then recovered and examined for presence of CM larvae. It is usually best to use this technique just prior to harvest and retrieve the bands after harvest.

SUMMARY:

Monitoring is critical to the success of an IPM program but is worthless or even misleading if not done properly. The cost of monitoring is usually offset by the ability to reduce pest control costs. Training existing orchard workers to conduct activities like trap checking can reduce the cost of some monitoring. Several tools are available to fruit growers for monitoring in mating disruption or conventional orchards. The key to success is to establish a monitoring program, maintain traps and lures, keep good records and stick with it year after year.

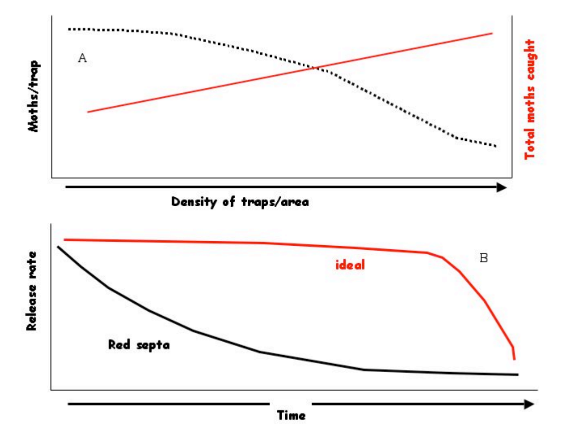

Figure 1: Theoretical relationship between trap density and moth captures (A). Ideal lure release rate vs. red septa (B).

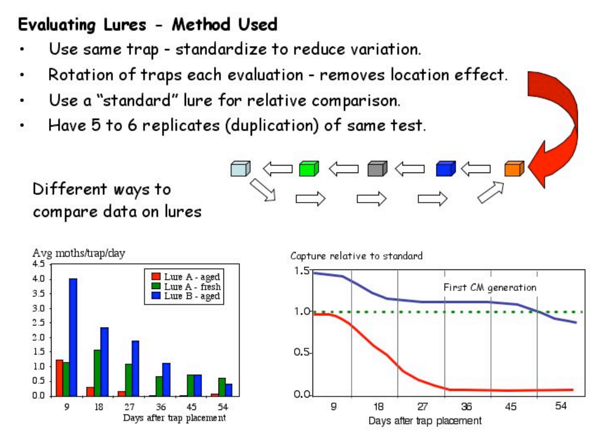

Figure 2: Lure testing methods.

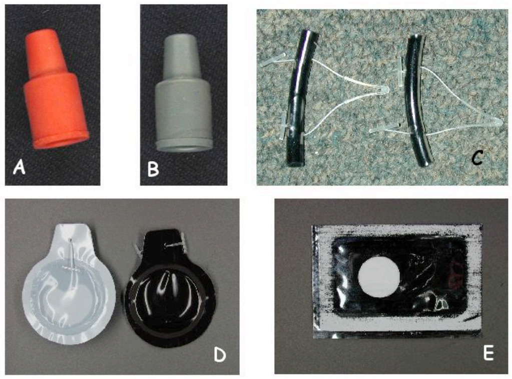

Figure 3: Lure types; Red septa (A), Gray Septa (DA Lure or MegaLure) (B), Flex Lure (C), SuperLure (D), BioLure (E).

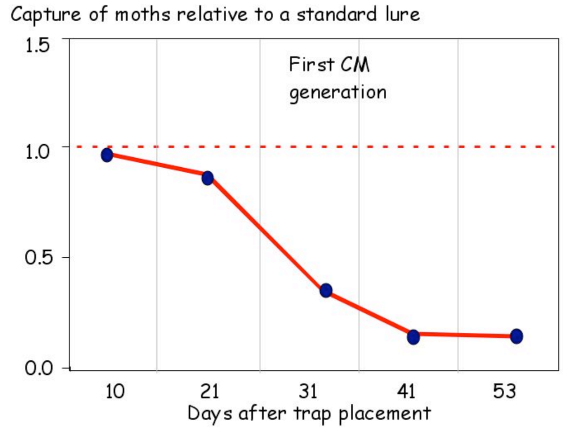

Figure 4: Relative attractancy of aged red septa over time during the first generation.

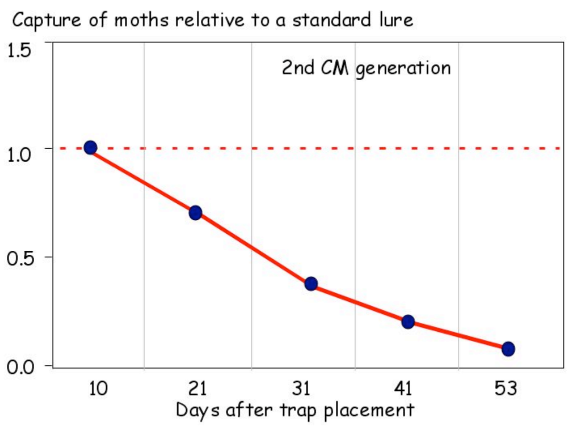

Figure 5: Relative attractancy of aged red septa over time during the second generation.

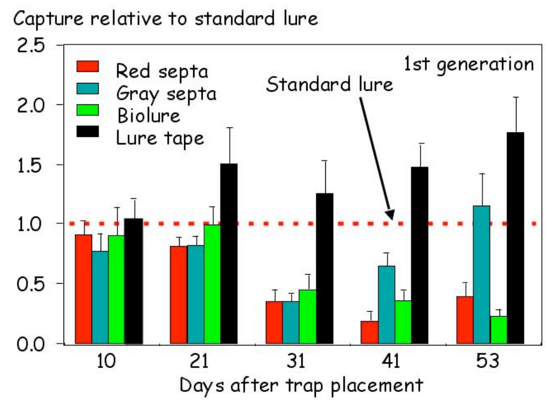

Figure 6: Relative attractancy of standard lures during the first generation.

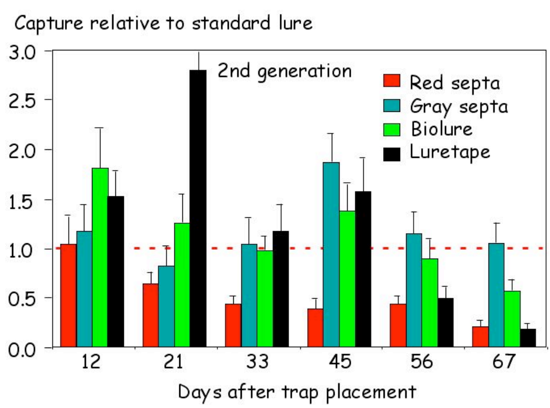

Figure 7: Relative attractancy of standard lures during the first generation.

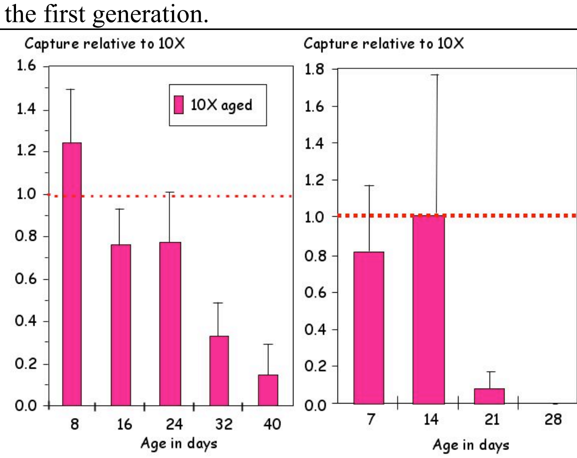

Figure 8: Relative attractancy of high-load lures during the first and second generation.

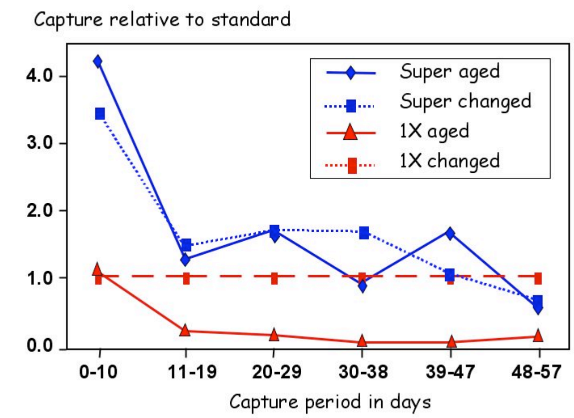

Figure 9: Relative attractancy of aged- or new SuperLures over time, first generation.

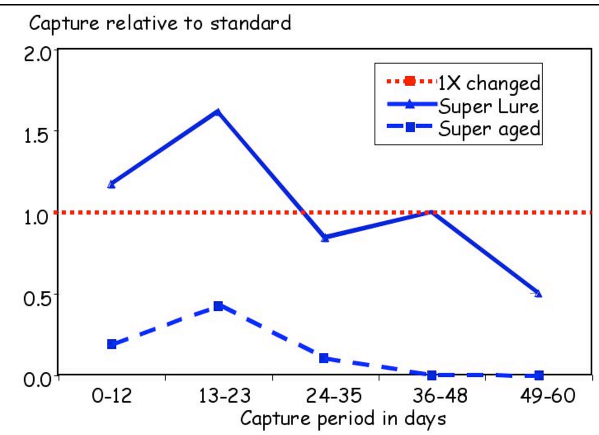

Figure 10: Relative attractancy of SuperLures over time, second generation.

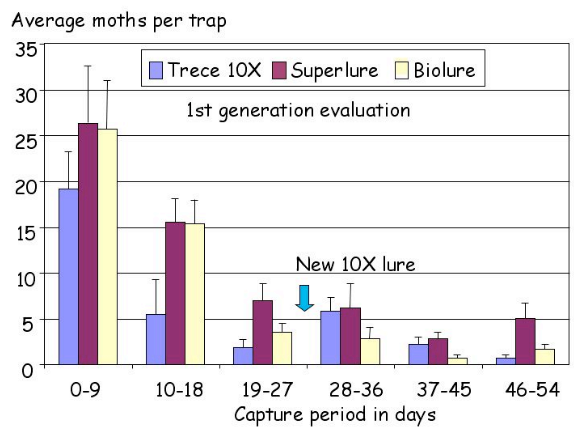

Figure 11: Relative attractancy of various high-load lures over time, first generation.

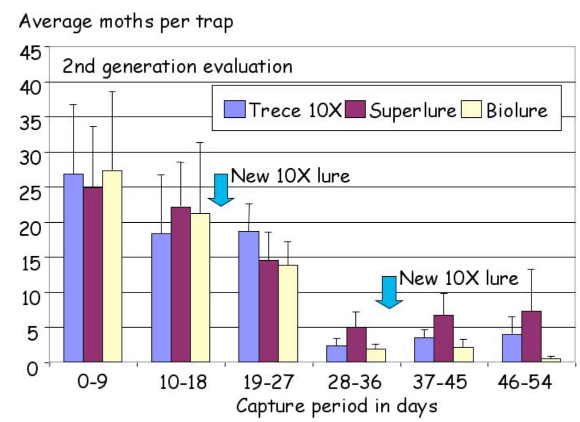

Figure 12: Relative attractancy of various high-load lures over time, second generation.

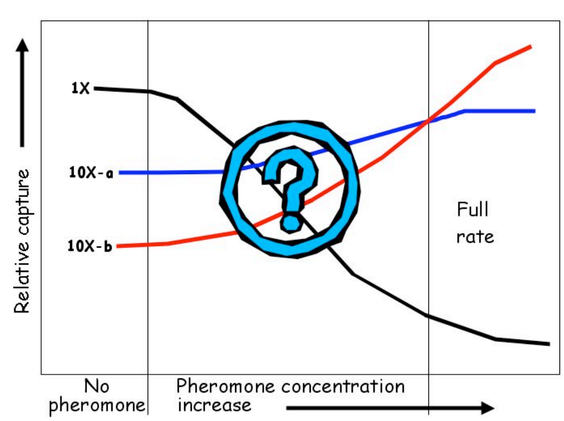

Figure 13: Theoretical attractancy of different load lures at different mating disruption dispenser densities.

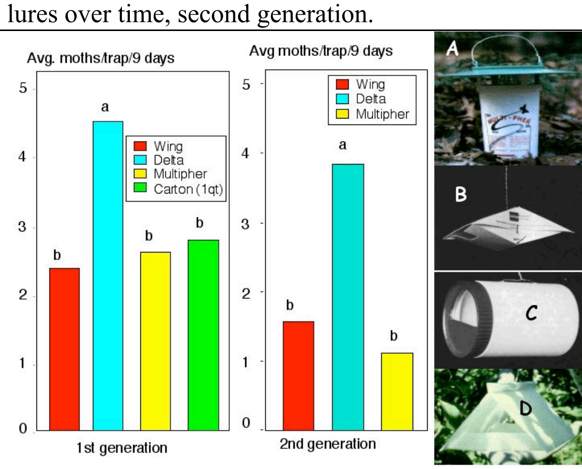

Figure 14: Relative efficacy of various trap types: Multipher (A), Wing (B), Carton (C), Delta (D).

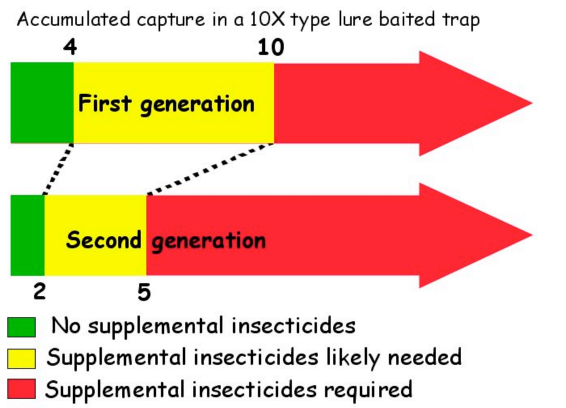

Figure 15: Treatment thresholds based on pheromone-baited trap captures.

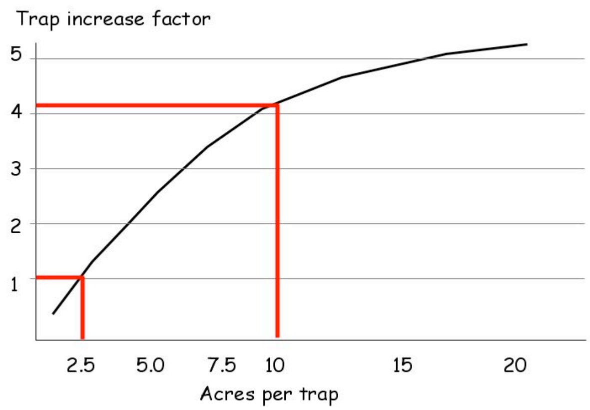

Figure 16: Theoretical relationship between trap density and moth captures.